Past study & next study plans for Slip Stacking

March 1st 02

Kiyomi Koba

Momentum aperture scan

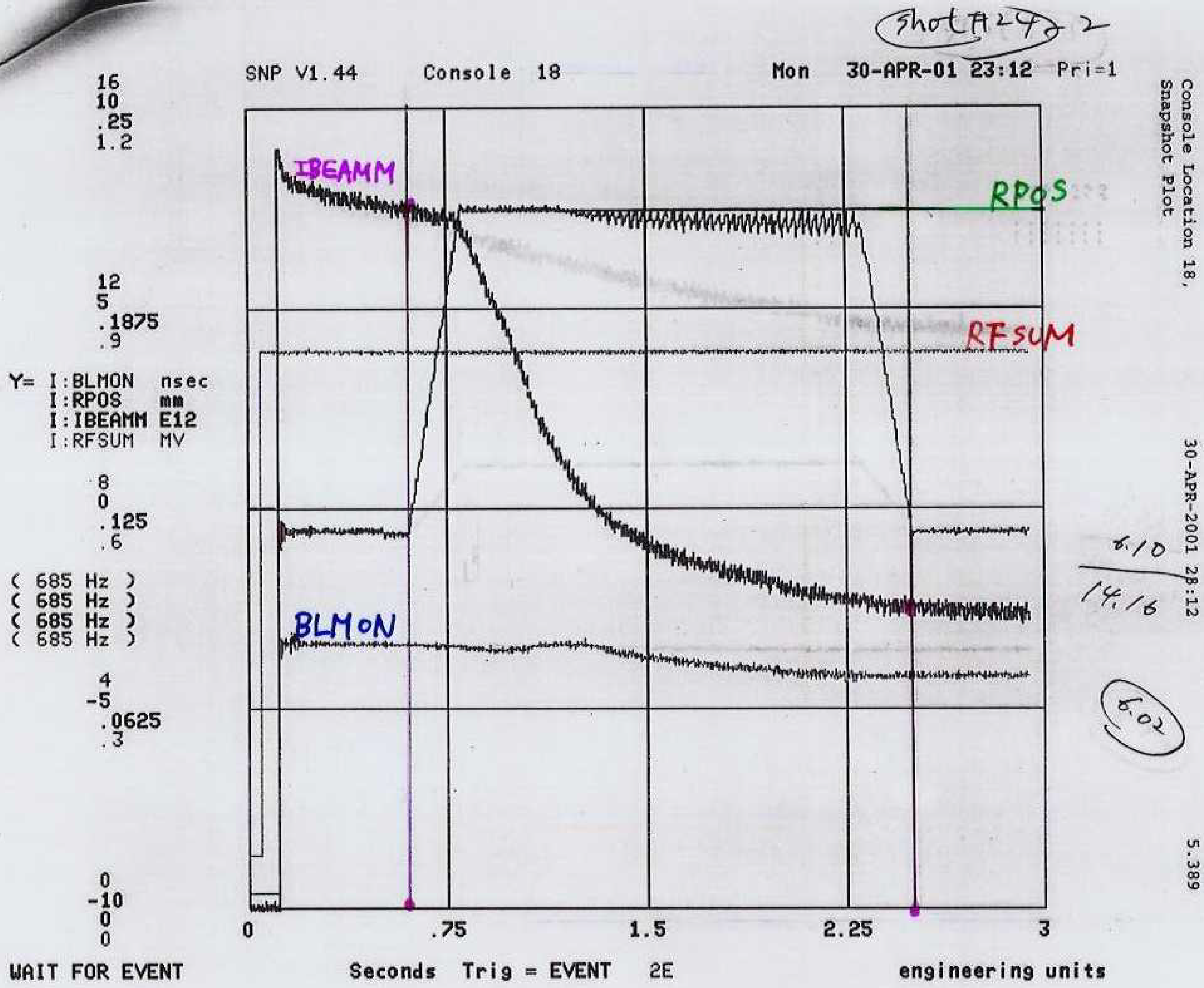
Phase rotation at Booster extraction

RF function

- Frequency separation

- Frequency function

Two batches injection and slipping



Shot A24 2
SNP V1.44
Console 18
Mon 30-APR-01 23:12 Pri=1
Console Location 18, Snapshot Plot
16
10
.25
1.2
12
5
.1875
.9
Y= I:BLMON nsec
I:RPOS mm
I:IBEAMM E12
I:RFSUM MV
8
0
.125
.6
(685 Hz)
(685 Hz)
(685 Hz)
(685 Hz)
4
-5
.0625
.3
0
-10
0
0
IBEAMM
RPOS
RFSUM
BLMON
30-APR-2001 23:12
6.10
14.16
6.02
5.389
0
.75
1.5
2.25
3
WAIT FOR EVENT
Seconds Trig = EVENT 2E
engineering units

GxPA 2: BPM DIFF Plot: 995 - 972

BPM DIFF Plot: 995 - 972

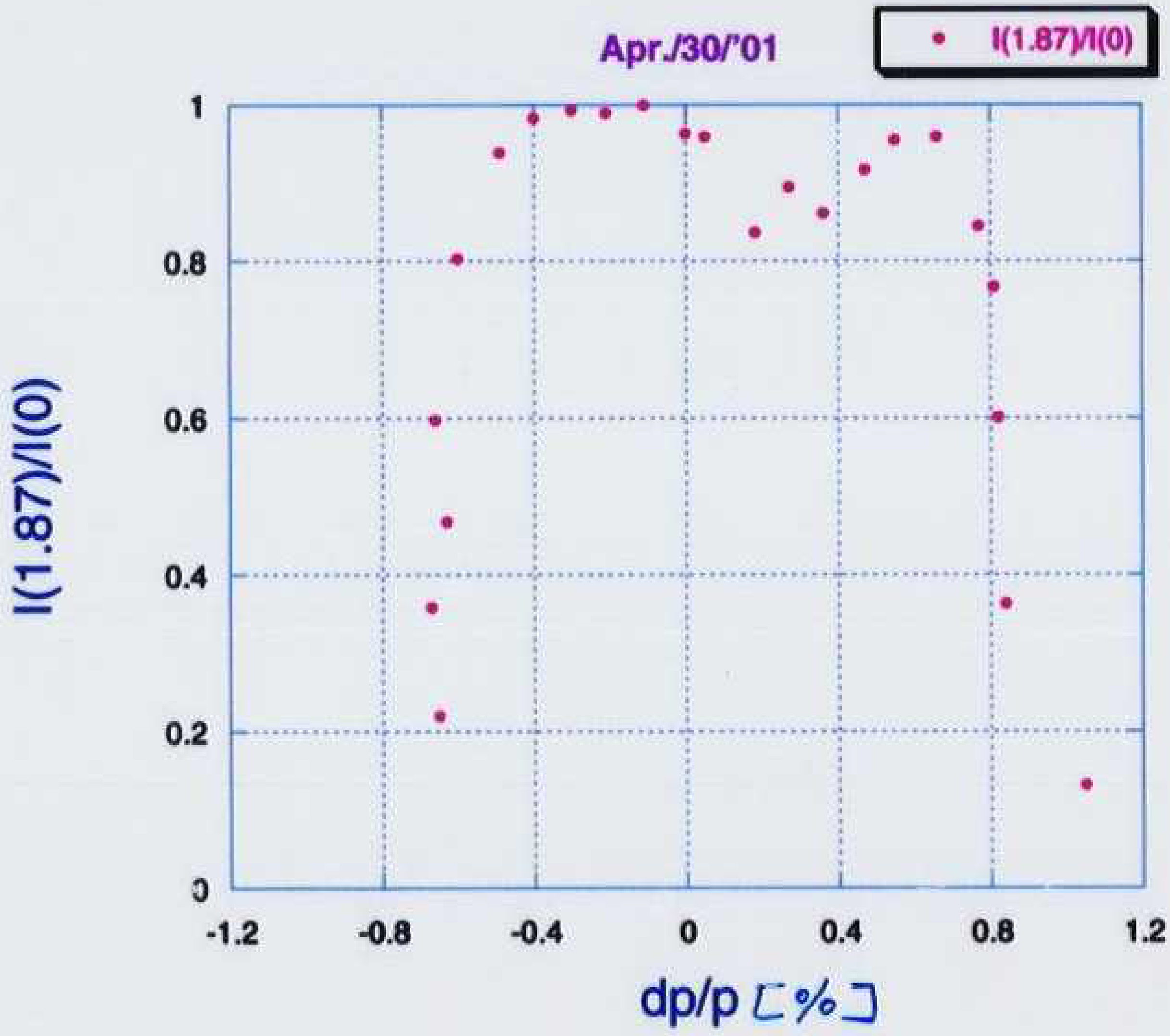
display - Frame 0

Horizontal

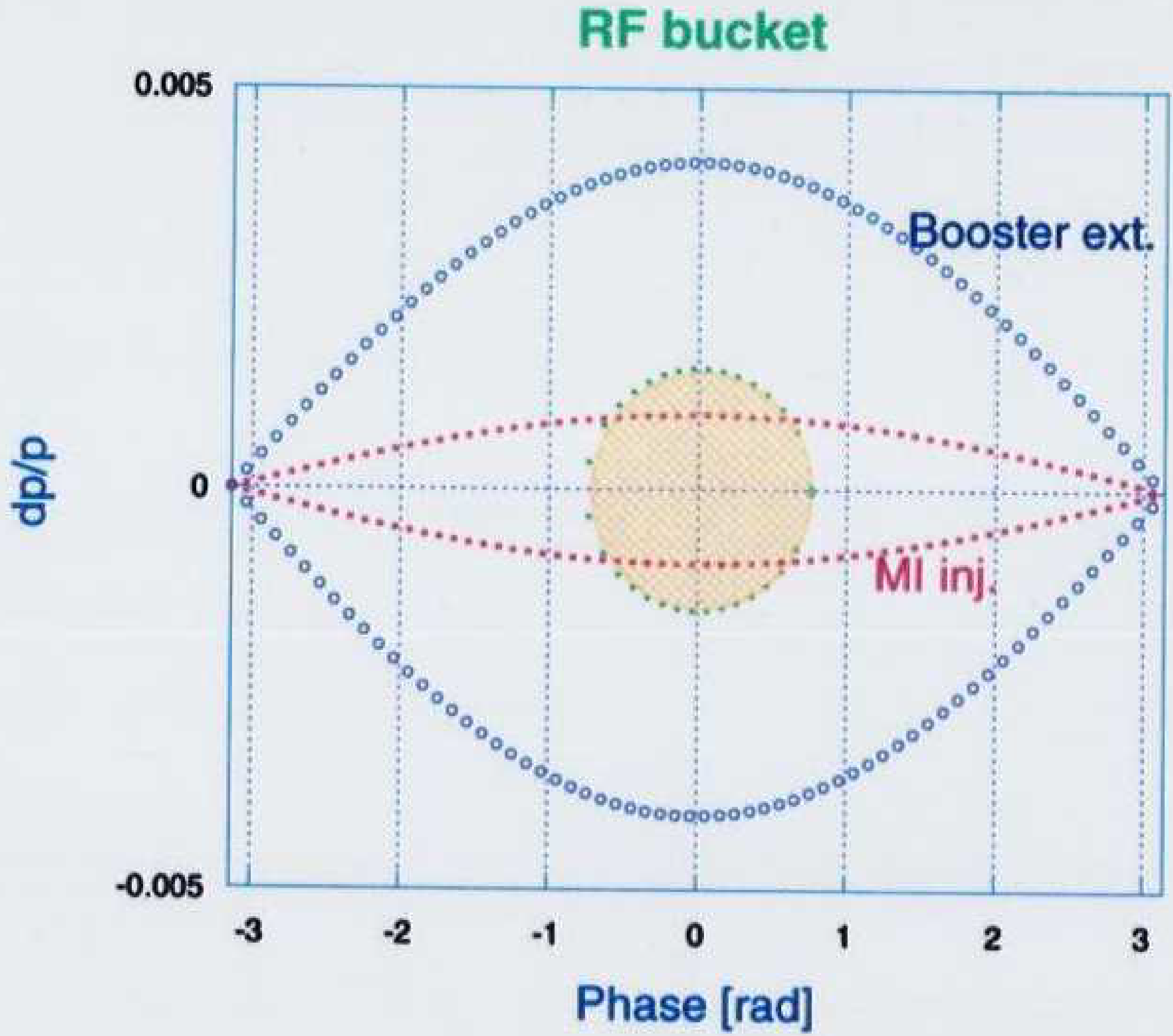
30-APR-2001 23:21:44

	10	20	30	40	50	60
00 ...	-.1017			0		
02 ...	0	-.1019	0	0	-.2101	-.2045
04 ...	.1019	.1017	.1017	0	0	.1019
06 ...	-.1018	-.1019	.1017	0	.1029	.5205
08 ...	0	-.2036	0	-.1059	.1017	0
10 ...	.1018	-.2108	-.1018	-.1018	-.2034	-.2034
12 ...	-.1017	.4068	.1017	.2037	.1022	.1022
14 ...	-.2034	-.1019	.2057	.1043	-.1017	.1017
16 ...	0	.2049	0	-.3321	0	0
18 ...	0	-.1147	-.1021	.2066	0	-.2042
20 ...	-.1031	.102	0	0	0	.5996
22 ...	-.2037	.7063	-.2056	0	0	.1052
24 ...	-.1017	-.1032	-.1018	-.1018	-.2771	-.2043
26 ...	0	0	0	0	-.2101	-.2043
28 ...	-.1017	.206	.1017	.1017	.1038	0
30 ...	-.1034	0	.1026	0	.1253	0
32 ...		.1023	.5103		-.2035	-.1017
34 ...			-.1019			-.2036
36 ...			0			.1017
38 ...			-.1018			.1017
40 ...			.1017			-.1017

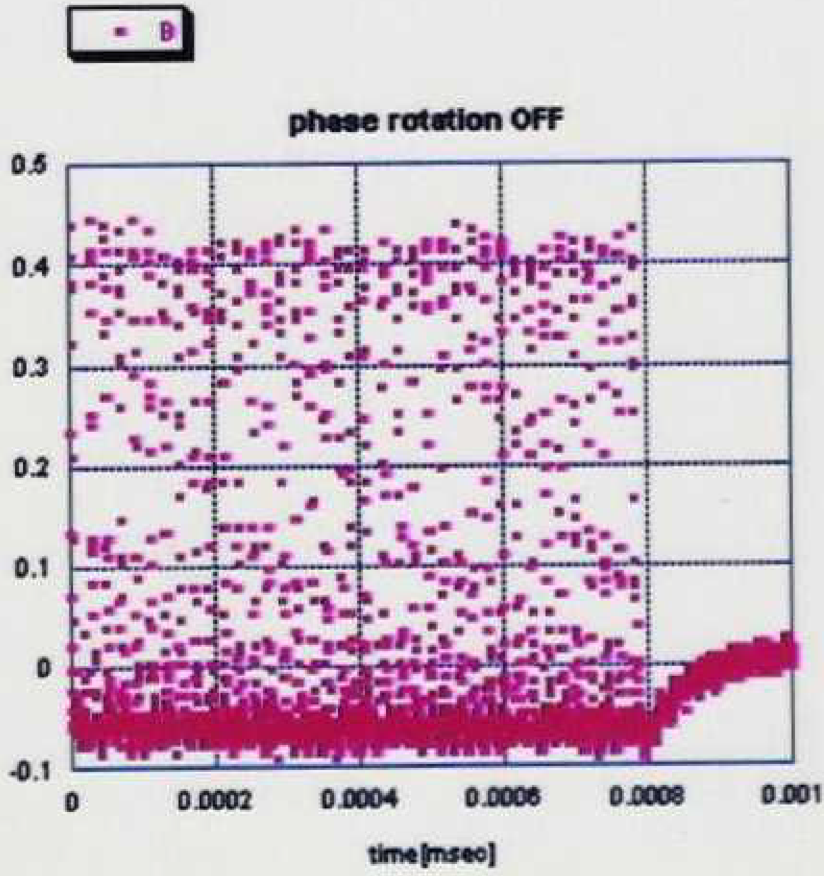
Close Duplicate



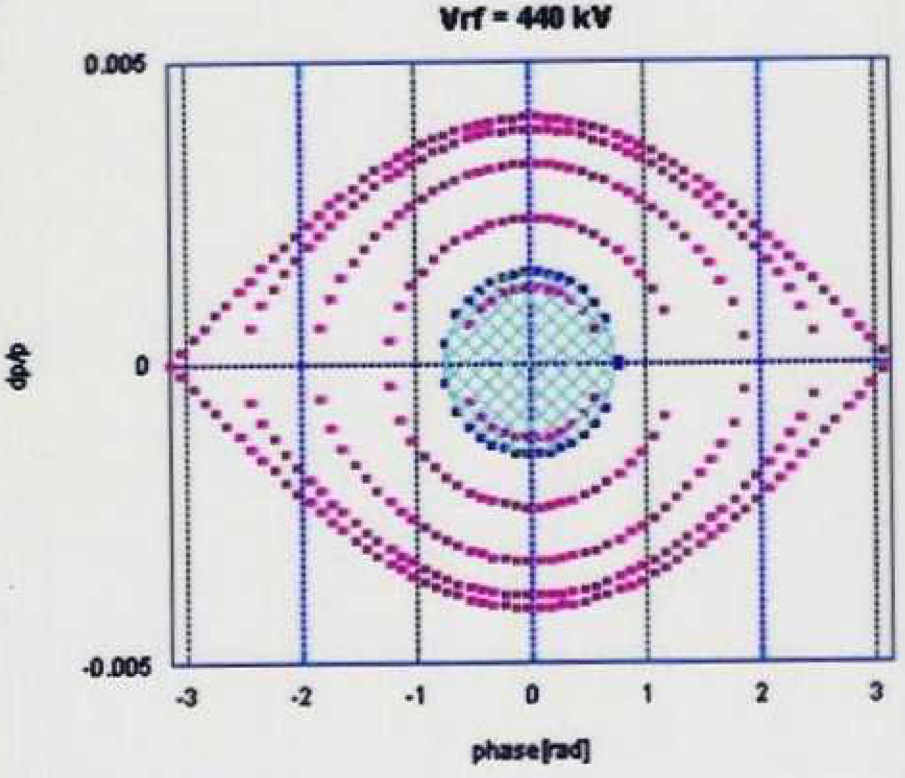
Apr./30/'01
I(1.87)/I(0)
1
0.8
0.6
0.4
0.2
0
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
dp/p [%]
I(1.87)/I(0)



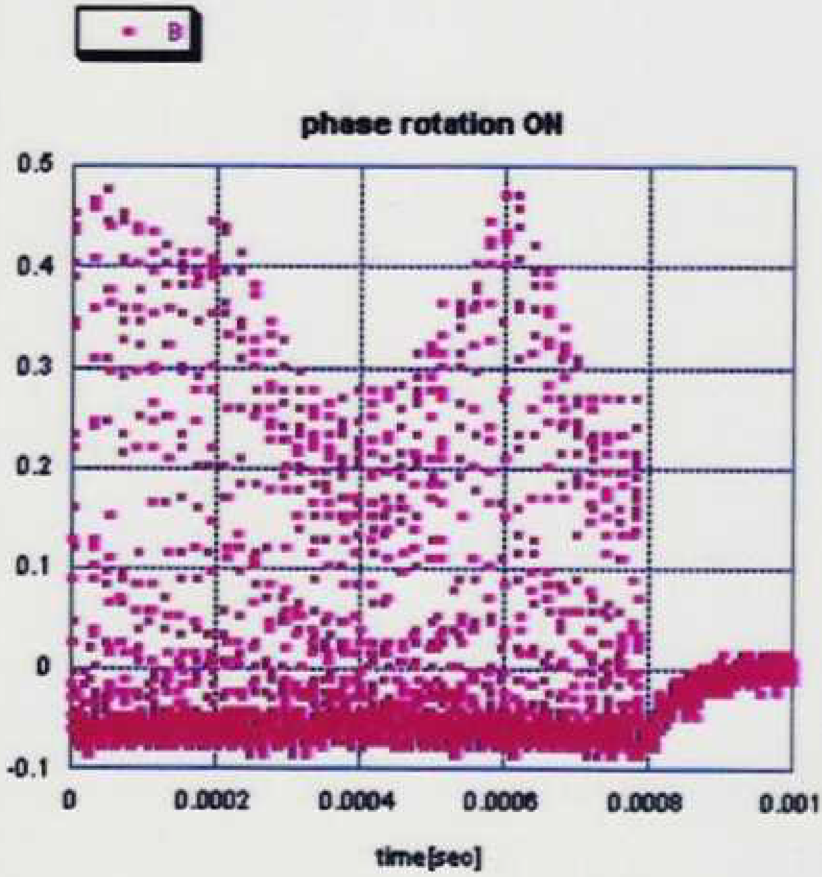
RF bucket
0.005
0
-0.005
dp/p
Booster ext.
MI inj.
-3
-2
-1
0
1
2
3
Phase [rad]



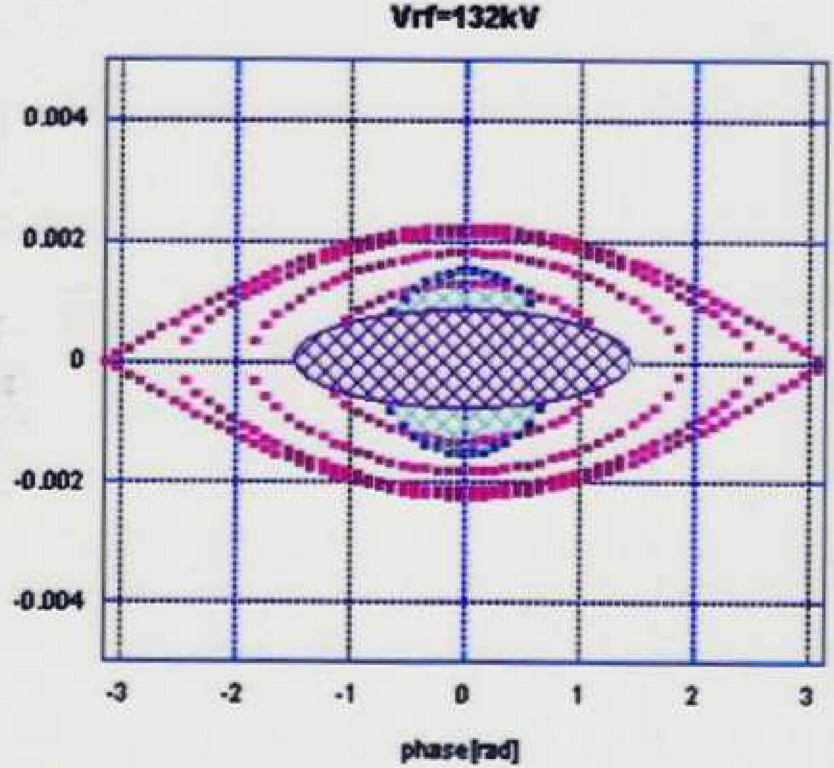
B
phase rotation OFF
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
0.0002
0.0004
0.0006
0.0008
0.001
time[msec]



Vrf = 440 kV
0.005
0
-0.005
dp/p
-3
-2
-1
0
1
2
3
phase[rad]



B
phase rotation ON
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
0.0002
0.0004
0.0006
0.0008
0.001
time[sec]

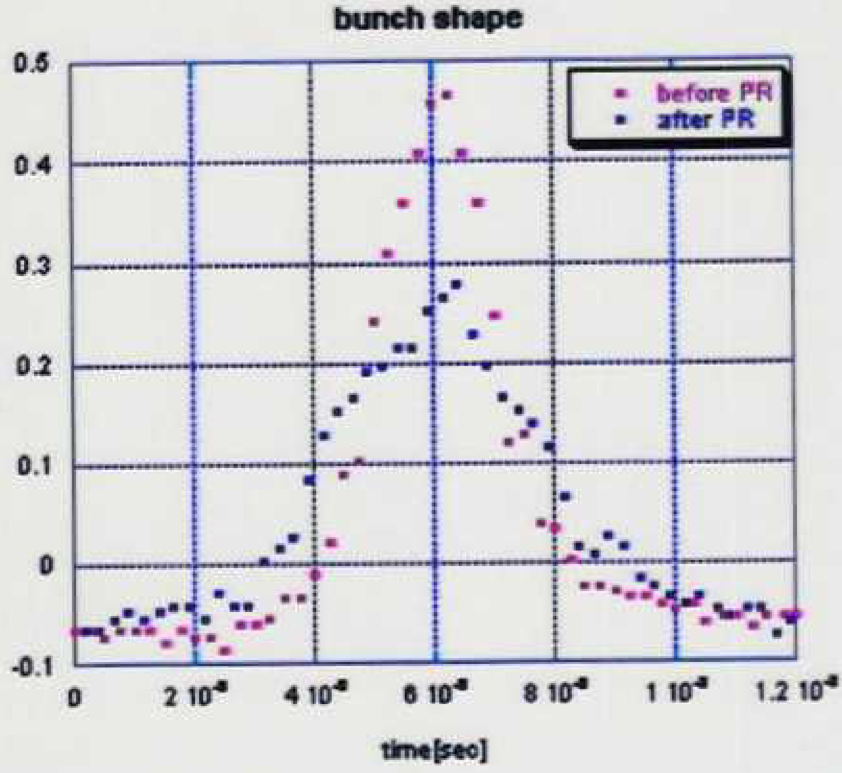


Vrf=132kV
0.004
0.002
0
-0.002
-0.004
dp/p
-3
-2
-1
0
1
2
3
phase[rad]

$(\phi, \Delta p/p) =$ $(0.242\pi, 0)$ $(0, 0.0015)$

$\frac{1}{4} \times \frac{1}{f_{sy}} \approx 195\ \mu sec$

$(0, 0.0082)$ $(0.478\pi, 0)$

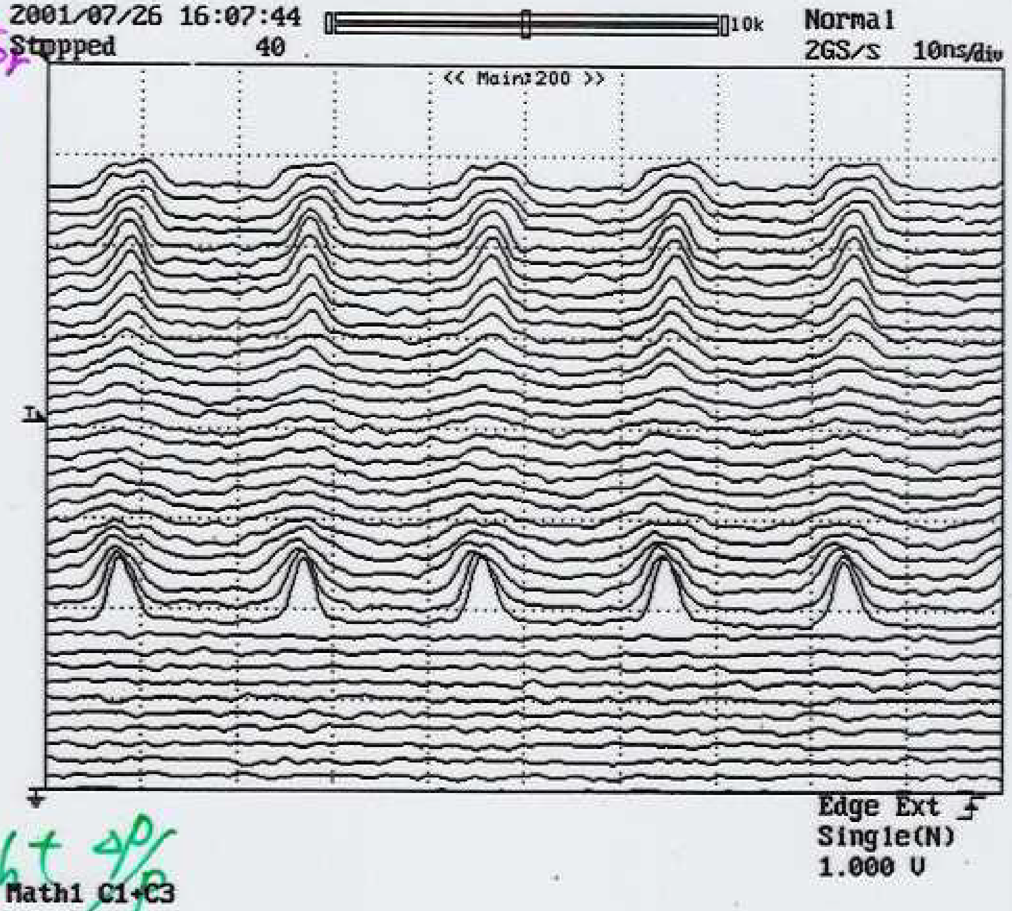


bunch length

0.242π

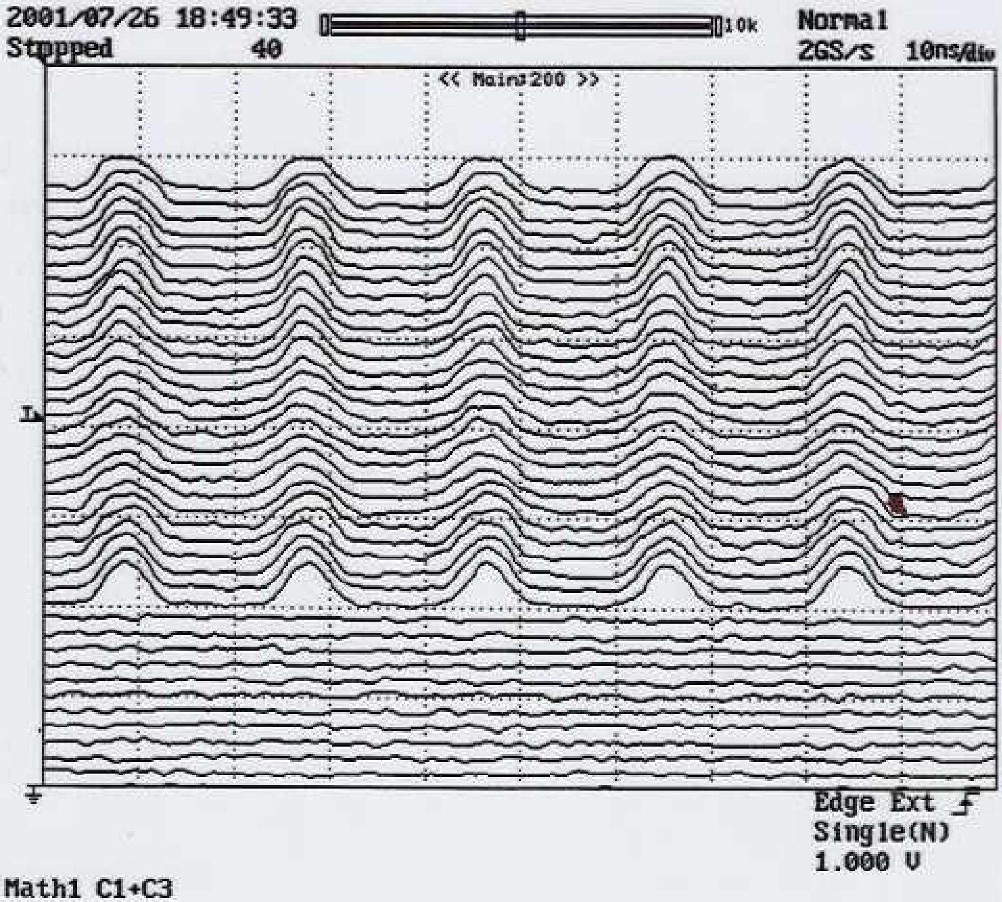
0.403π

@ Main Injector injection.

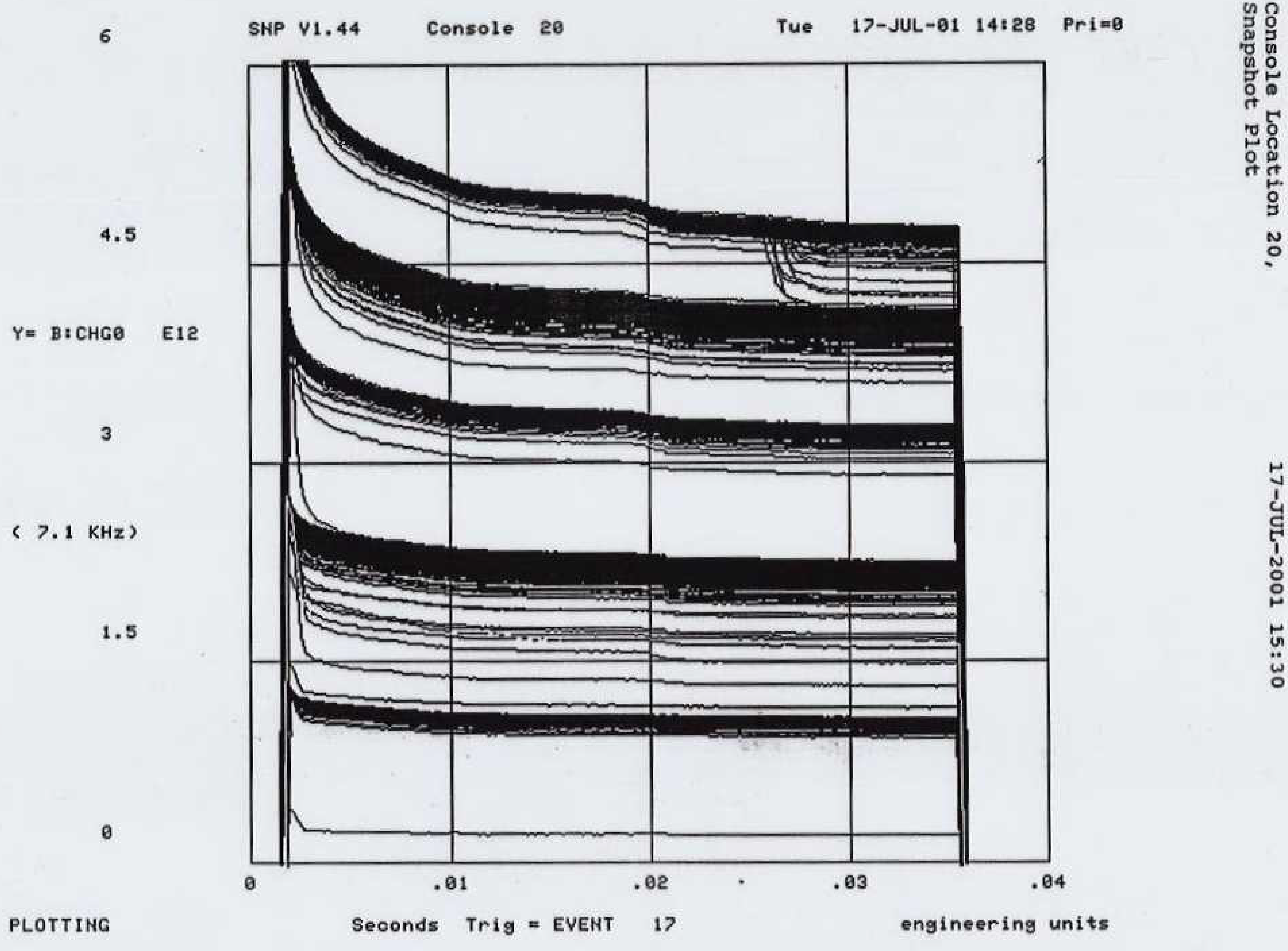


PR OFF

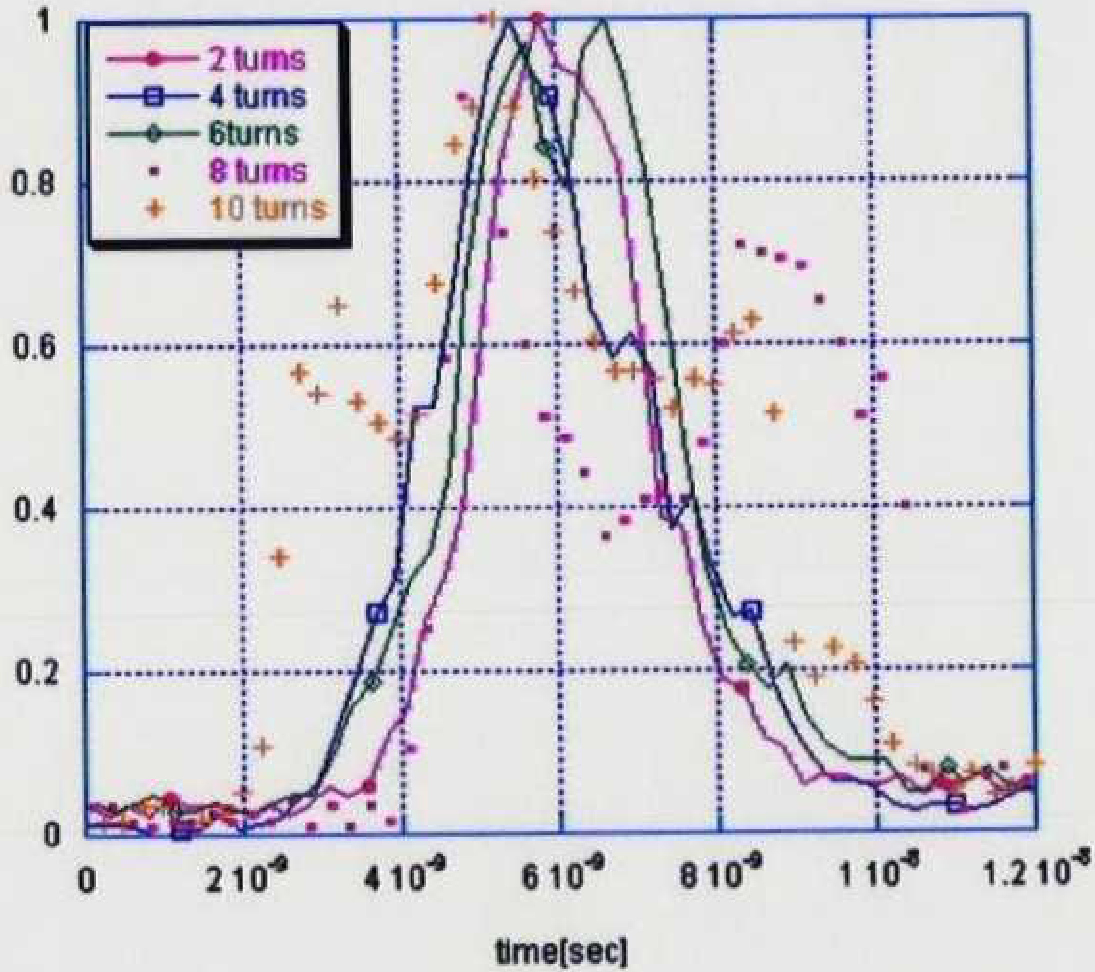
bucket height $\Delta p/p$ = 0.00087

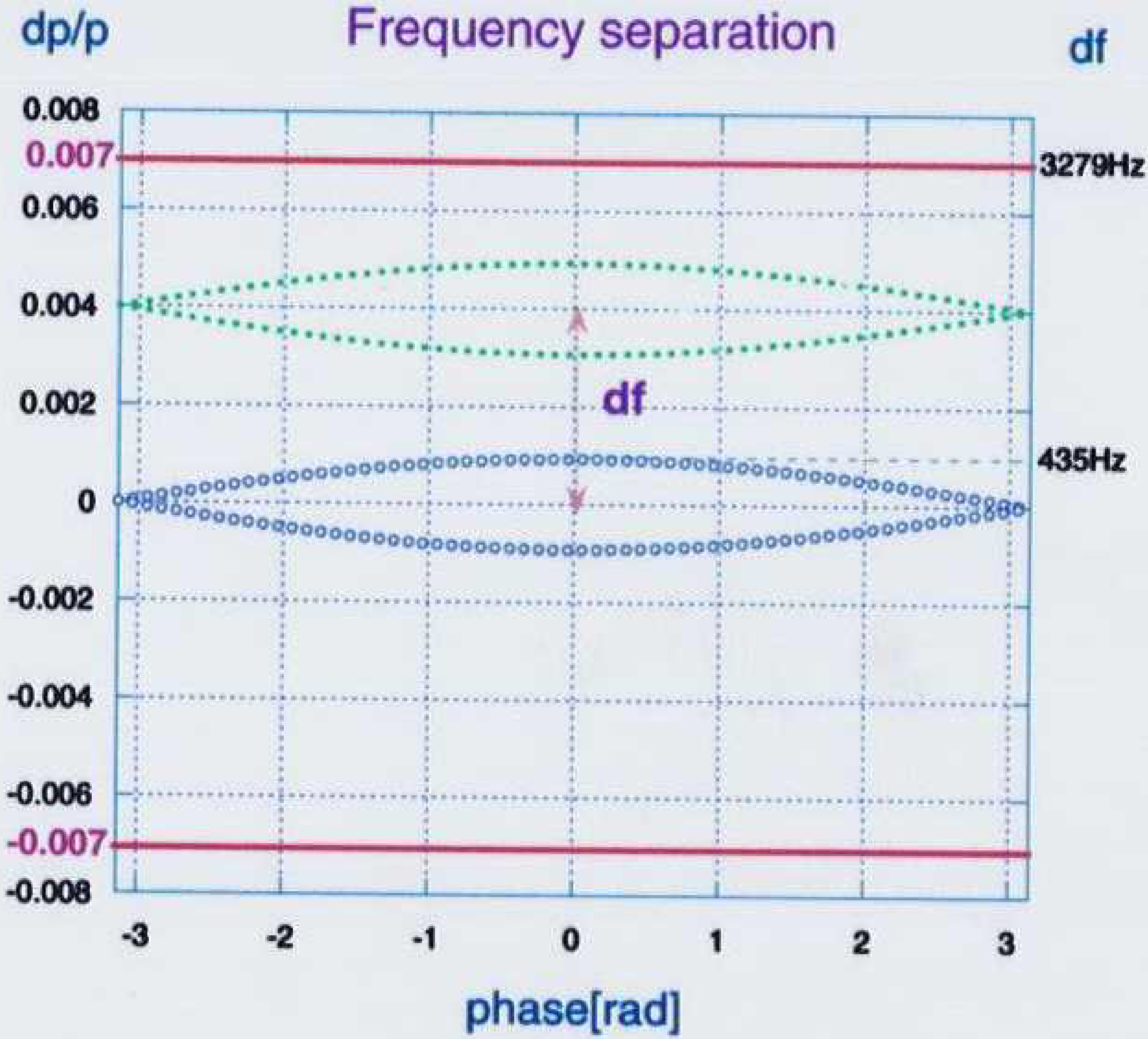


PR ON

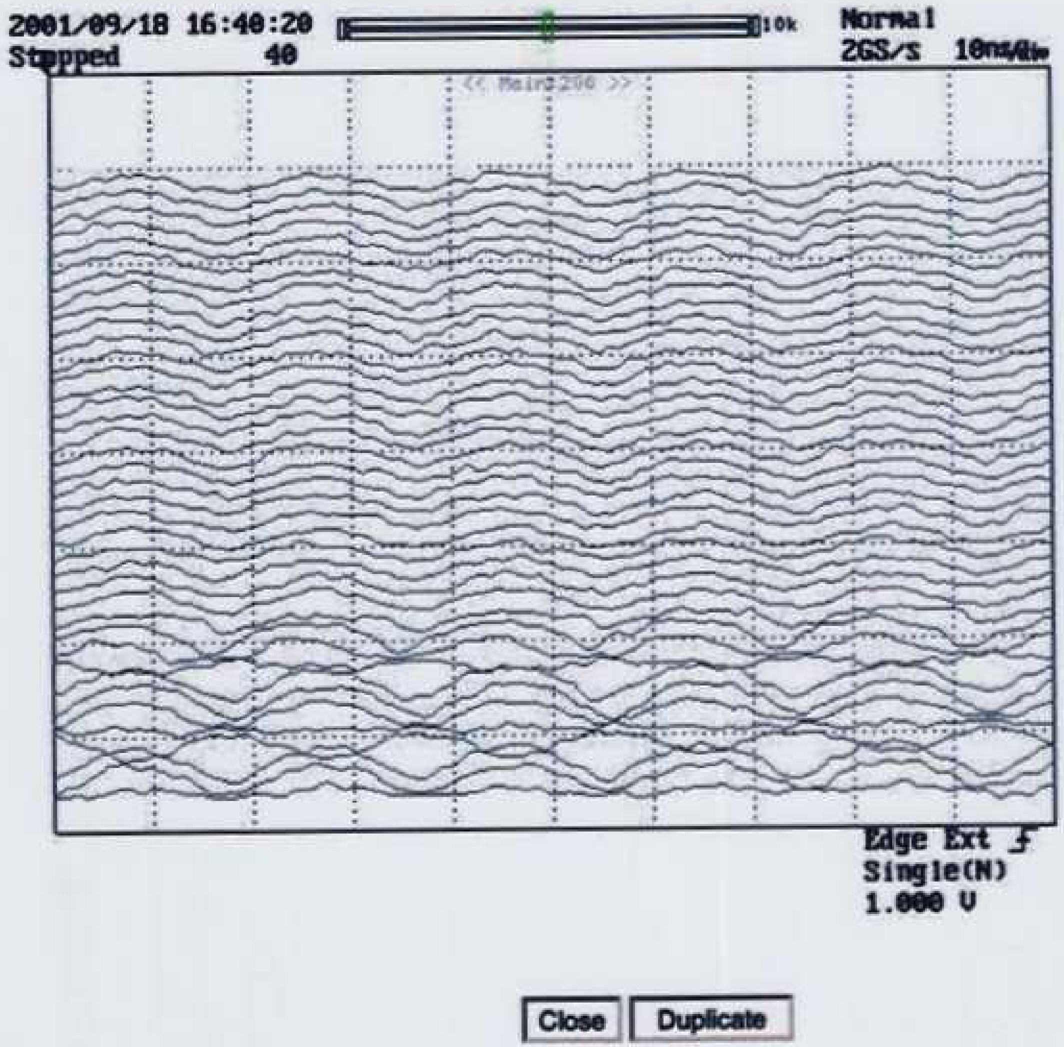


SHP V1.44
Console 20
Tue 17-JUL-01 14:28 Pri=0
Console Location 20,
Snapshot Plot
6
4.5
Y= B:CHG0 E12
3
(7.1 KHz)
1.5
0
0
.01
.02
.03
.04
17-JUL-2001 15:30
PLOTTING
Seconds Trig = EVENT 17
engineering units

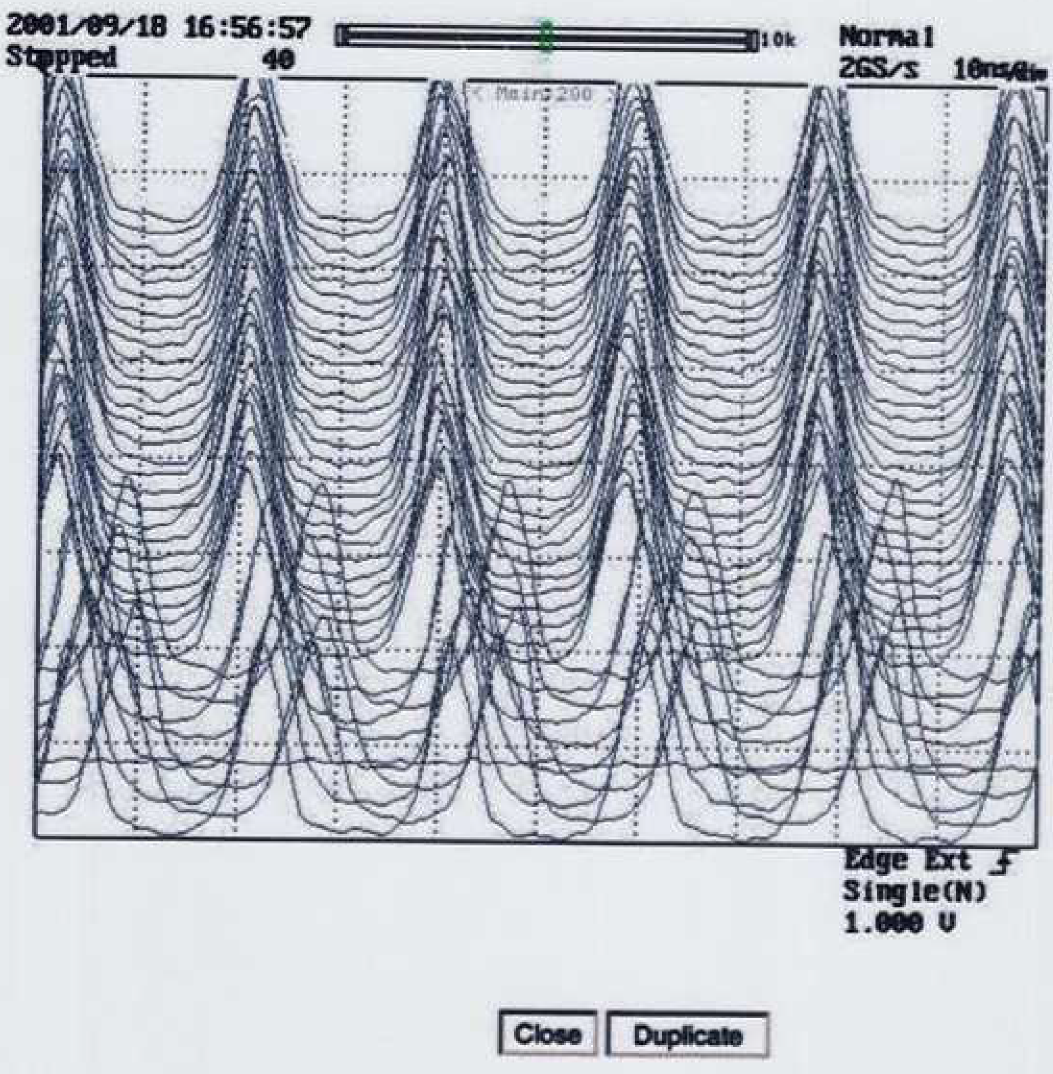

2 turns
4 turns
6turns
8 turns
10 turns
1
0.8
0.6
0.4
0.2
0
0
2 10-9
4 10-9
6 10-9
8 10-9
1 10-8
1.2 10-8
time[sec]



Frequency separation
dp/p
df
0.008
0.007
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.007
-0.008
3279Hz
435Hz
df
-3
-2
-1
0
1
2
3
phase[rad]



$\Delta f = 400 Hz$

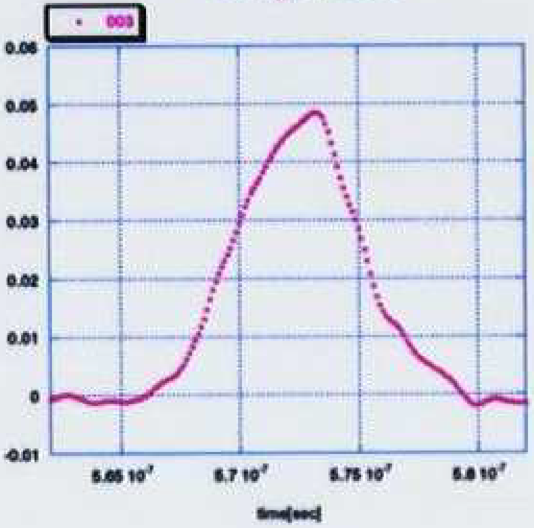


$\Delta f = 1000 Hz$

@ 0.12 sec

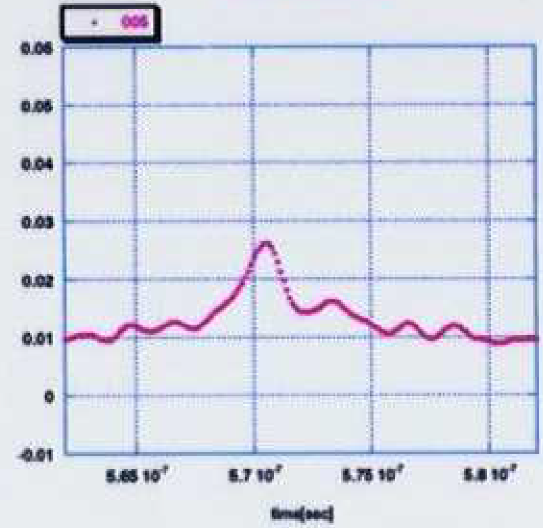
@ 0.27 sec

@injection



df= 400Hz

df= 600Hz

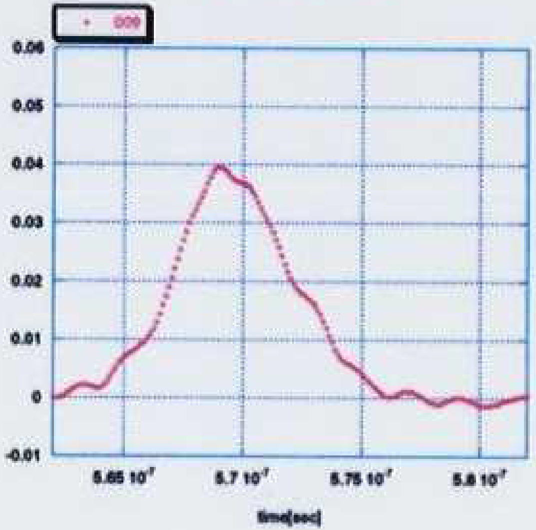


df= 800Hz

df= 1000Hz

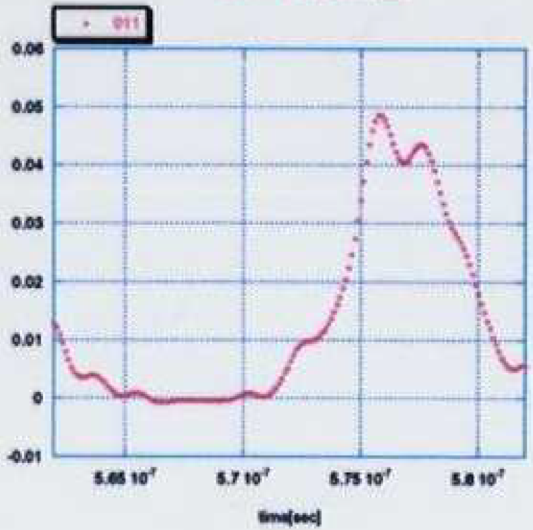
df= 1200Hz

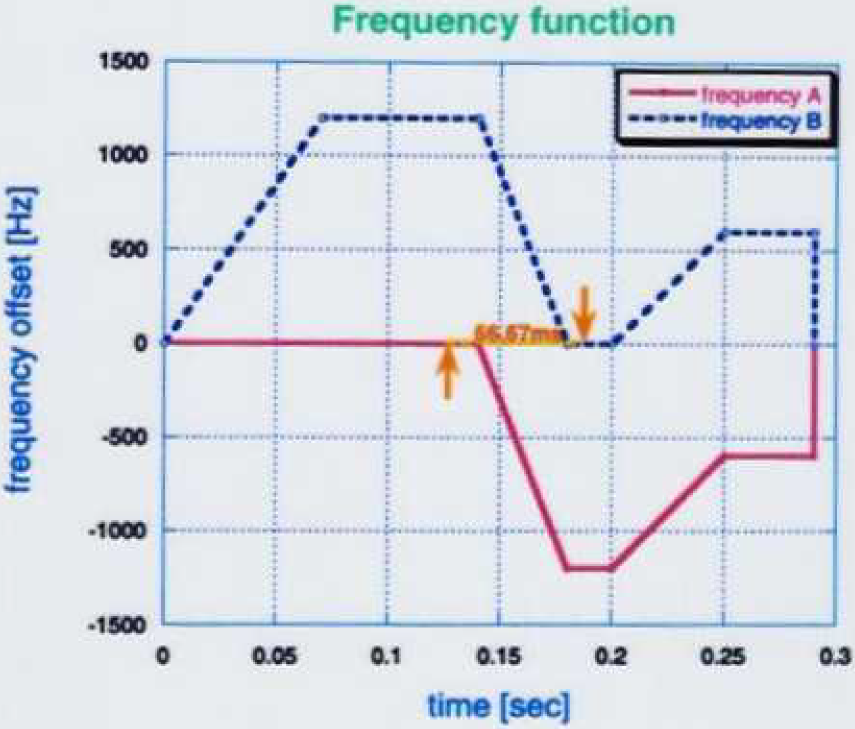
df=1400Hz

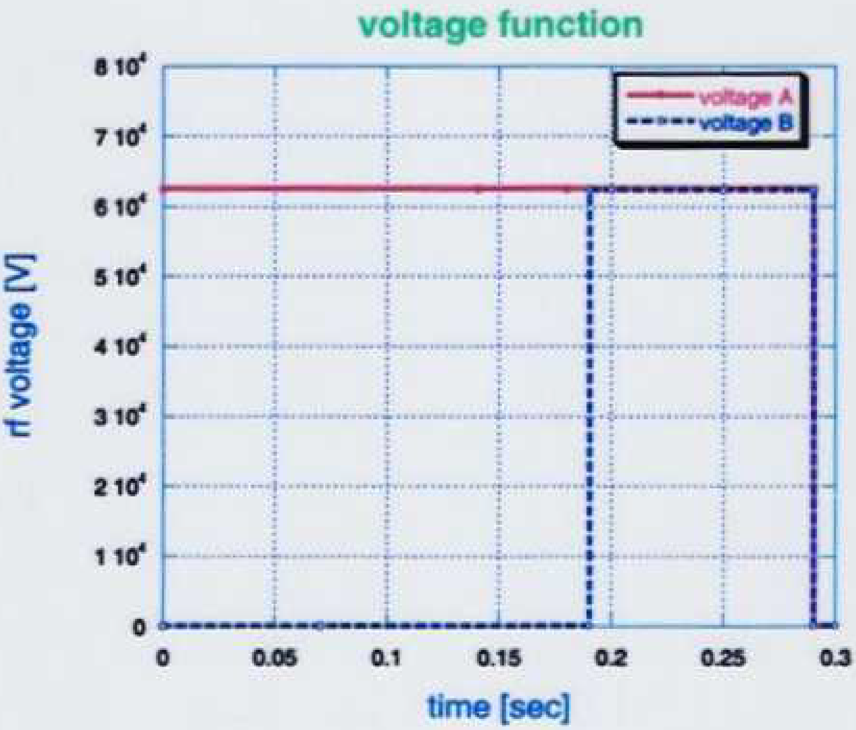


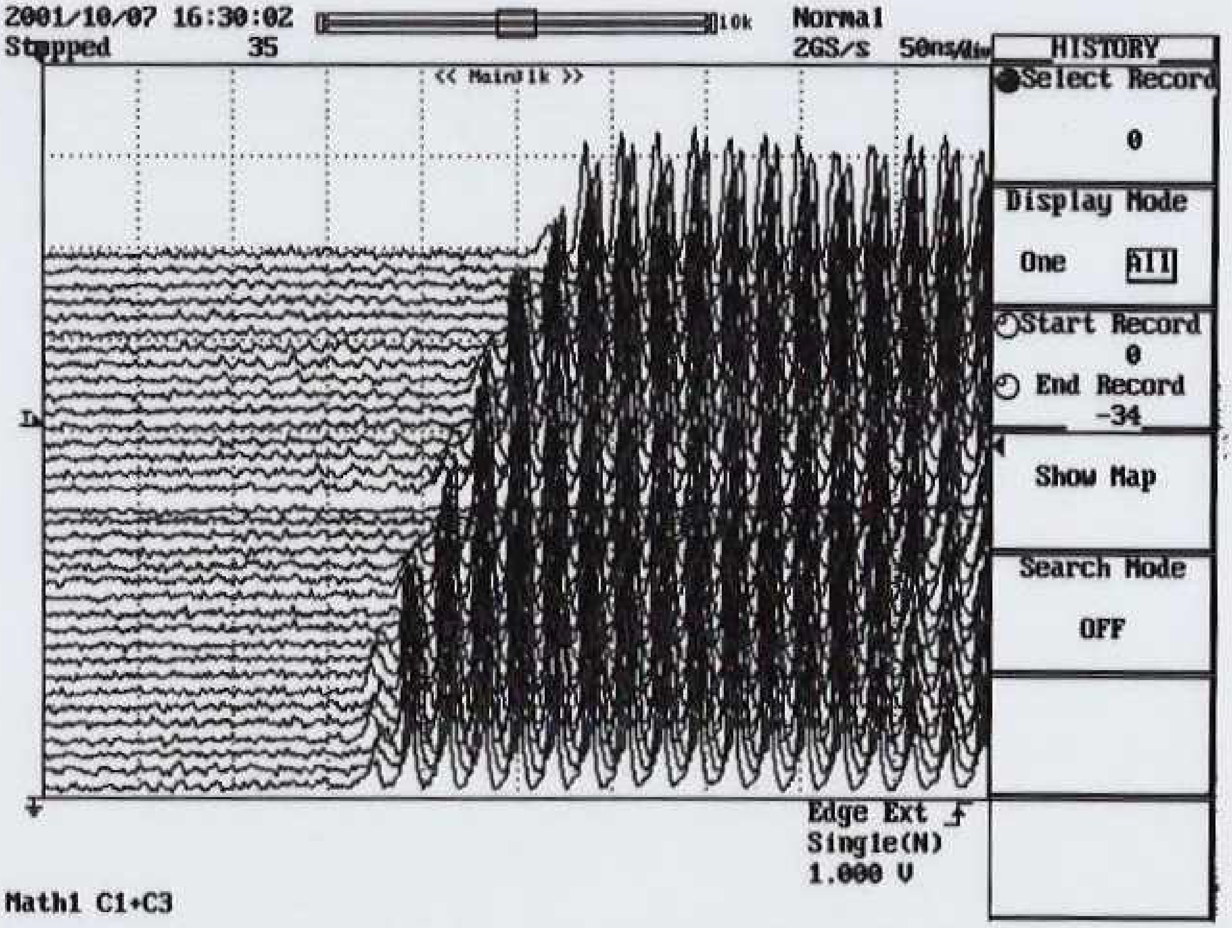
df=1600Hz

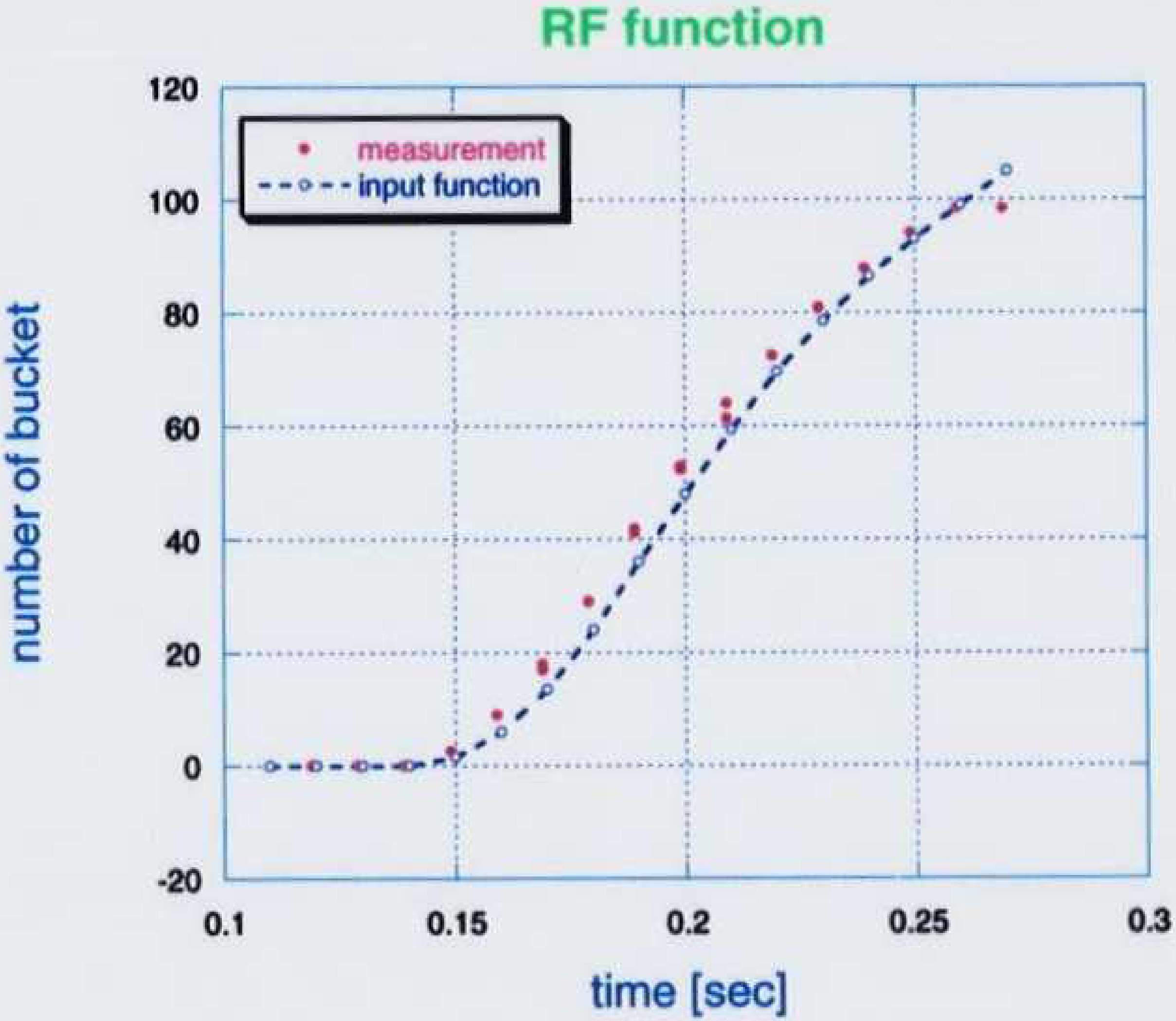
df=1800Hz

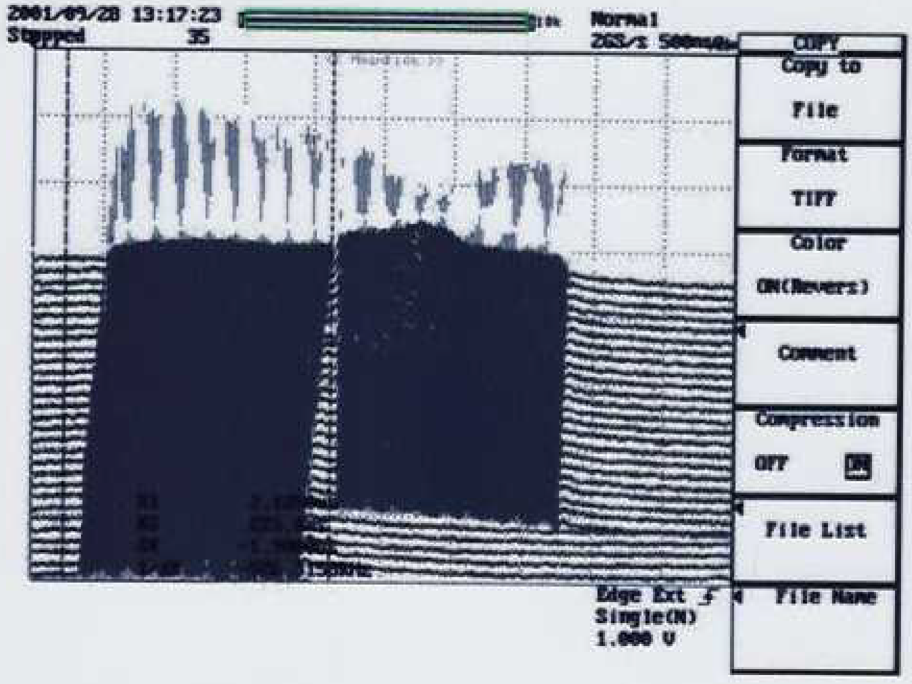


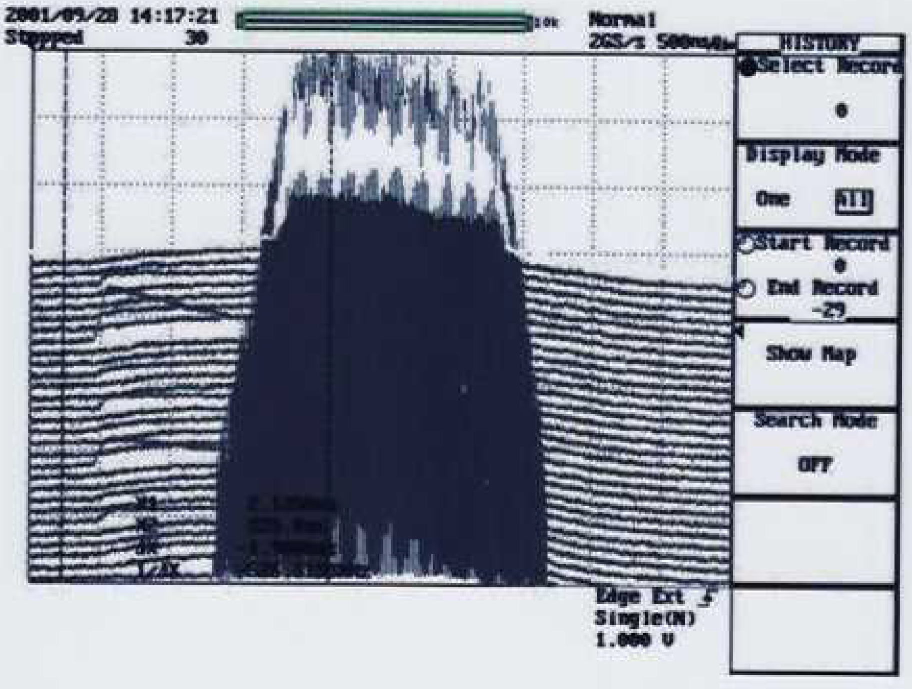

Frequency function
frequency A
frequency B
frequency offset [Hz]
1500
1000
500
0
-500
-1000
-1500
0
0.05
0.1
0.15
0.2
0.25
0.3
time [sec]

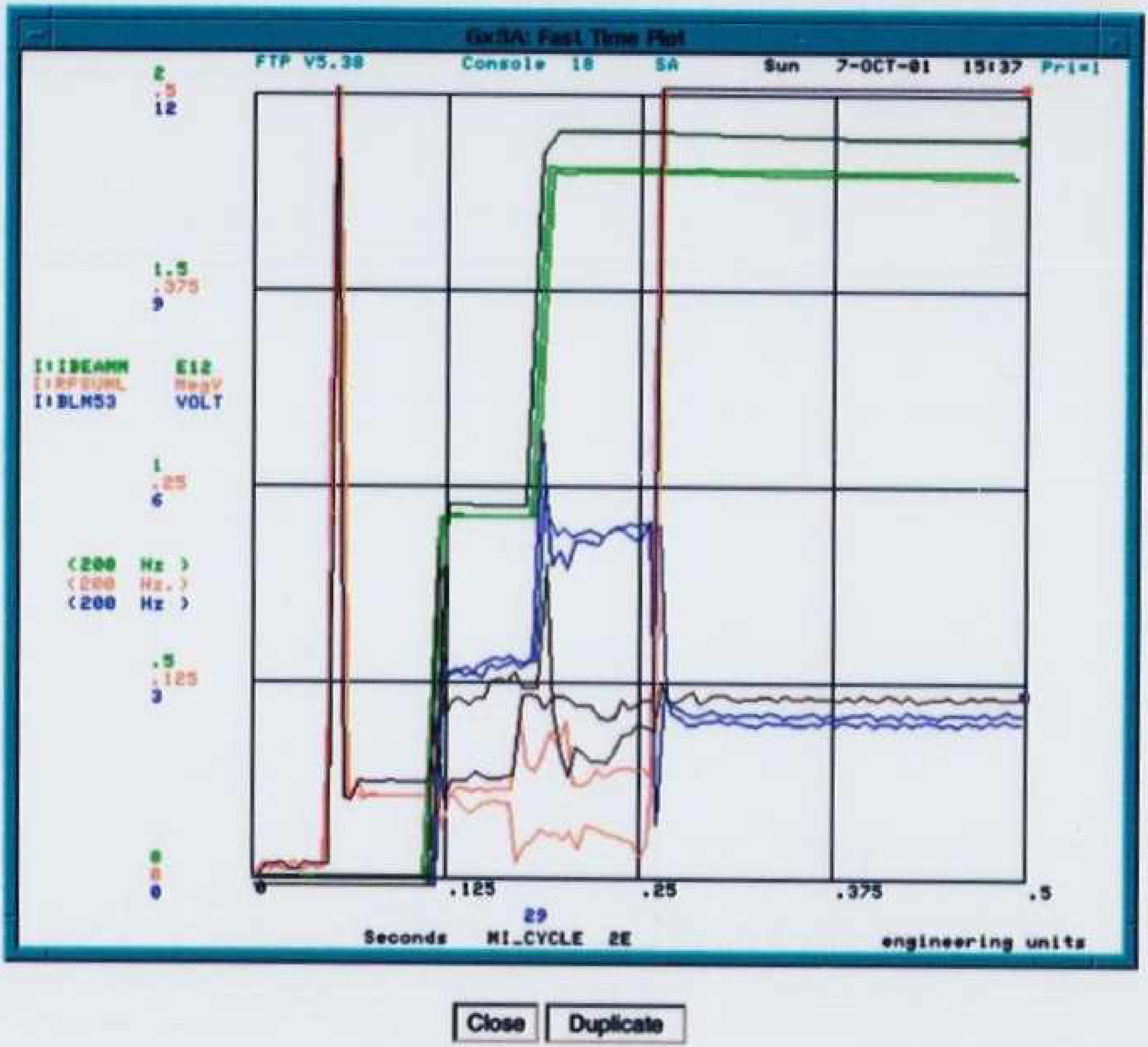

voltage function
voltage A
voltage B
rf voltage [V]
8 10^4
7 10^4
6 10^4
5 10^4
4 10^4
3 10^4
2 10^4
1 10^4
0
0
0.05
0.1
0.15
0.2
0.25
0.3
time [sec]


2001/10/07 16:30:02
Stopped 35
10k
Normal
2GS/s 50ns/div
<< Main:1k >>
HISTORY
Select Record
0
Display Mode
One All
Start Record
0
End Record
-34
Show Map
Search Mode
OFF
Edge Ext
Single(N)
1.000 V
Math1 C1+C3


RF function
measurement
input function
number of bucket
time [sec]
120
100
80
60
40
20
0
-20
0.1
0.15
0.2
0.25
0.3


2001/09/28 13:17:23
Stopped 35
Normal
2GS/s 500ns/div
COPY
Copy to File
Format TIFF
Color ON(Revers)
Comment
Compression OFF ON
File List
File Name
Edge Ext
Single(N)
1.000 V


2001/09/28 14:17:21
Stopped 30
Normal
2GS/s 500ns/div
HISTORY
Select Record 0
Display Mode One All
Start Record 0
End Record -29
Show Map
Search Mode OFF
Edge Ext
Single(N)
1.000 V



Gx:SA: Fast Time Plot
FTP V5.38
Console 18
SA
Sun 7-OCT-01 15:37 Pri=1
2
.5
12
1.5
.375
9
I:IBEAMM E12
I:RFSUML MegV
I:BLM53 VOLT
1
.25
6
(200 Hz)
(200 Hz)
(200 Hz)
.5
.125
3
0
0
0
0
.125
.25
.375
.5
29
Seconds MI_CYCLE 2E
engineering units
Close
Duplicate

Plan

Synchronize two batches re-capture

Optimize RF function

- Frequency separation
- Emittance preservation during acceleration and deceleration
- Re-capture voltage, angle and phase

High intensity beam injection with Booster damper

Beam loading effects

BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

AADD-176

ACCELERATOR DEPARTMENT
Internal Report

STABILITY OF PHASE OSCILLATIONS UNDER TWO APPLIED FREQUENCIES

F.E. Mills
June 2, 1971

Abstract

Stability criteria are developed for the stability of motions of particles in a bucket while subjected to an acceleration voltage at small frequency difference $\Delta\nu$. The motion is stable if $\Delta\nu \geqslant 10\nu_s$ where ν_s is the phase oscillation frequency. This is essentially the same criterion as that the buckets not touch.

I. Introduction

We would like to investigate the stability of particle motion in nearly stationary rf buckets when subjected to a neighboring rf frequency. Intuitively we surmise that the particles in a bucket are subjected to, primarily, the difference frequency of the two rf systems, and that since the perturbing voltage appears at all phases, resonances will appear in the phase oscillations when $\Delta\nu = n\nu_s$, where $\Delta\nu$ is the difference frequency, ν_s is the phase oscillation frequency and $n = 1, 2, ---$. Clearly $n = 1$ corresponds to the excitation of coherent phase oscillations, $n = 2$ to bunch shape type oscillations (or half integral resonance), $n = 3$ and higher to the type of resonances which determine limits of stability of motion. We note further that the frequency of phase oscillations <u>decreases</u> with amplitude, so that if a stability criterion is found for small amplitude motion, larger amplitude will be <u>more</u> stable, for a given frequency difference. The purpose of this note is to estimate the stopband widths associated with these resonances.

IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

PRODUCTION OF BEAMS WITH HIGH LINE-DENSITY BY AZIMUTHAL COMBINATION OF BUNCHES IN A SYNCHROTRON

D. Boussard* and Y. Mizumachi**

Summary

Simultaneous acceleration of several beams in the machine by several RF fields of slightly different ...ncies was already considered a long time ago[1,2]. ...ey rotate at different frequencies, the bunches ...eriodically coincide in azimuth, thus producing ...of high local line density. Bunches rotating at ... frequencies can be produced either outside ...chine (e.g. in the injector) or even inside by ...riate modulation of the RF cavities. These tech... will be used in the p-$\bar{p}$ project at CERN. A high ...nsity proton beam, necessary for antiproton pro..., is obtained in the CPS by azimuthal combina... either at the injection or at the ejection level. ...other hand, the antiproton bunches in the SPS ...e azimuthally combined before storage in order to ... the design luminosity. Computer simulation and ...ipulations of these procedures, as well as experi... results already obtained at the CPS, are pre...

...nch behaviour when submitted to two RF waves

...e assume that two sets of bunches, called B_1 and ... having different energies are circulating in the ...machine. Each beam is hopefully held bunched by ...own RF wave of frequency f_1, f_2 respectively. The ...tion is to see whether bunches B_1 feel only the ...uency f_1 and vice-versa. Intuitively we know that ...the frequency difference is large the frequency f_2 ...far from being synchronous with bunches B_1 and its ...ect will be small. More precisely the total RF wave ... be considered as the wave f_1 strongly modulated in ...itude and phase (100% modulation) at the difference ...quency $\Delta f = f_2 - f_1$. From this, one expects a large ...ect when the ratio $\alpha = \Delta f/f_s$ (f_s: synchrotron fre...ncy corresponding to one wave) becomes of the order ...unity. It has been shown[2]) that an approximate con...tion for beam independence is that the buckets do not ...ch, which, for stationary buckets, corresponds to ... condition $\alpha > 4$. A computer simulation has been ... in order to evaluate the bunch distortions as a ...ction of α and the bunch size[3]). The bunch is ...sumed to be matched at the beginning of the process. ...g. 1 shows a typical case $\alpha = 4$, for various bunch ...es. The condition $\alpha > 4$, already mentioned, does ... correspond to a sharp threshold, even for small bun...es. Distortion increases rapidly for larger bunches.

Estimates for much longer drifting periods have been obtained in an experiment on the SPS machine. On a 10 GeV/c "flat bottom" two RF cavities were used to hold the bunches (almost full buckets) at frequency f_1, while the third cavity was powered at frequency f_2. Bunch emittance was estimated from the height of a wide band pickup electrode signal. Small blow-up after 50 synchrotron periods is obtained for $\alpha = 5.6$, while for $\alpha = 4.4$ the effect of frequency f_2 appears clearly after a few periods.

2. Combination of two bunches

When drifting the two sets of bunches periodically coincide in azimuth, which doubles the local line density. This high line density beam can be used directly, for instance to produce short and intense bursts of secondary particles ($\bar{p}$) after fast ejection. The bunch pairs can also be combined in a single large bucket at a frequency $(f_1 + f_2)/2$. Here, the critical parameter is the final beam emittance. Minimum blow-up requires a small frequency separation and relatively small bunch distortion, which are unfortunately two contradictory requirements.

a) First example, CPS injection[4,5])

Bunches B_1 are produced in one CPS booster ring (or possibly by two CPS booster rings vertically recombined[4])) whose RF frequency is set to f_1. A group of five CPS cavities is driven by f_1, with the proper phase and amplitude to match bunches B_1. Bunches B_2 coming from another booster ring are trapped in the same way (5 cavities, f_2). Bunches B_1 and B_2 are separated by at least one RF period and must drift by 5(+1,-0) RF periods to be superimposed. As the bunch area to bucket area ratio is small (8 mrad/18 mrad) the expected bunch distortion is little. By counting an integer number of periods of the difference frequency $f_2 - f_1$, one generates a trigger pulse which starts the combination. All ten RF cavities are then connected to the normal phase loop system and their voltage set to the maximum (20 kV) to provide maximum acceptance (~ 50 mrad). In order to avoid phase transients, the phase lock system is presynchronized on f_1 during the drifting period. If frequencies f_1 and f_2 are held constant the two beams spiral inwards because of the rising magnetic field which limits α to about 5. They can also be programmed to give no radial displacement which allows more flexibility.

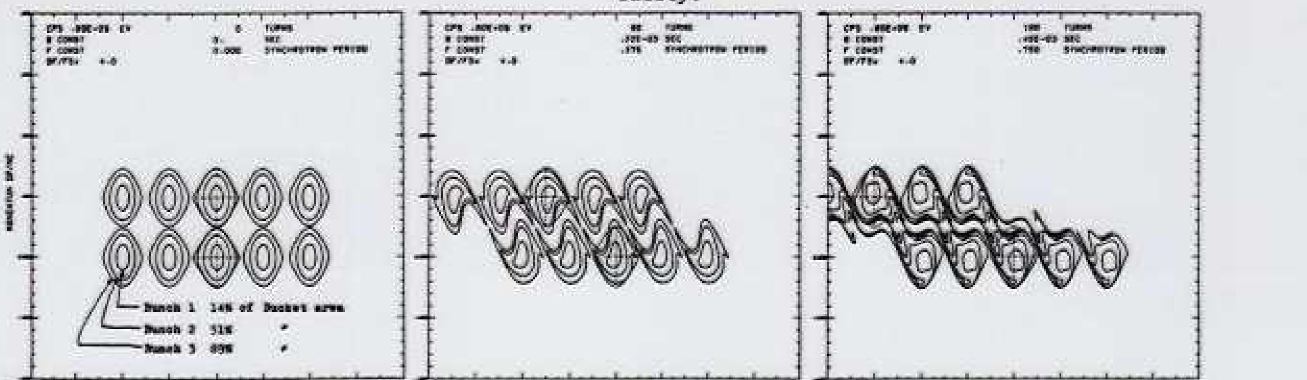
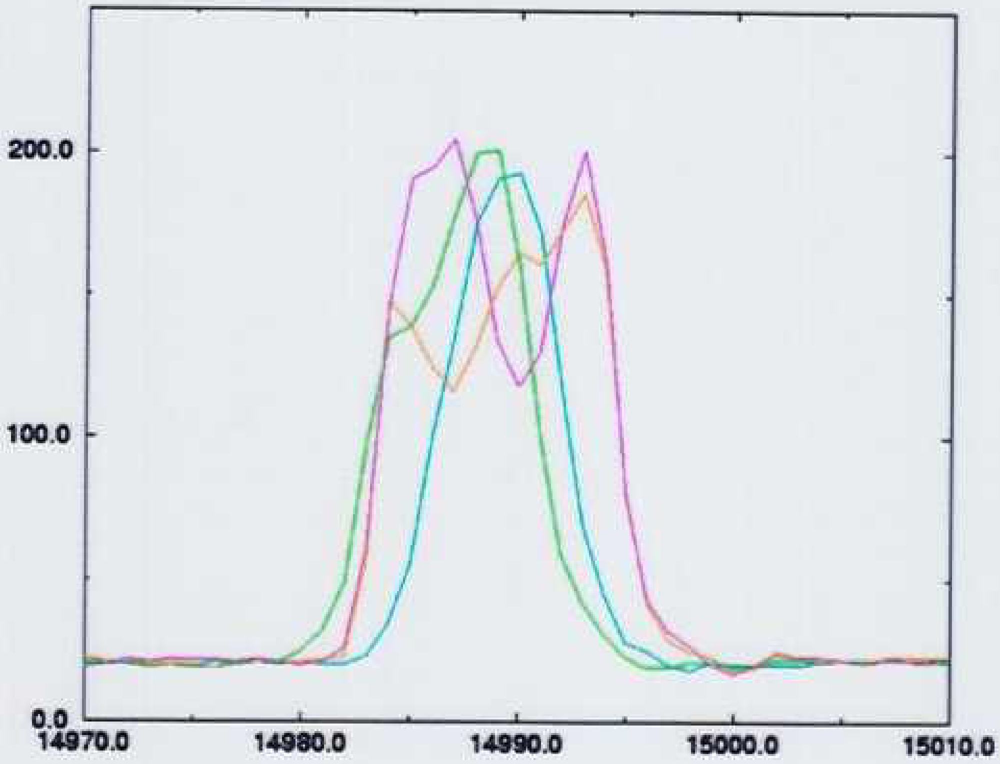
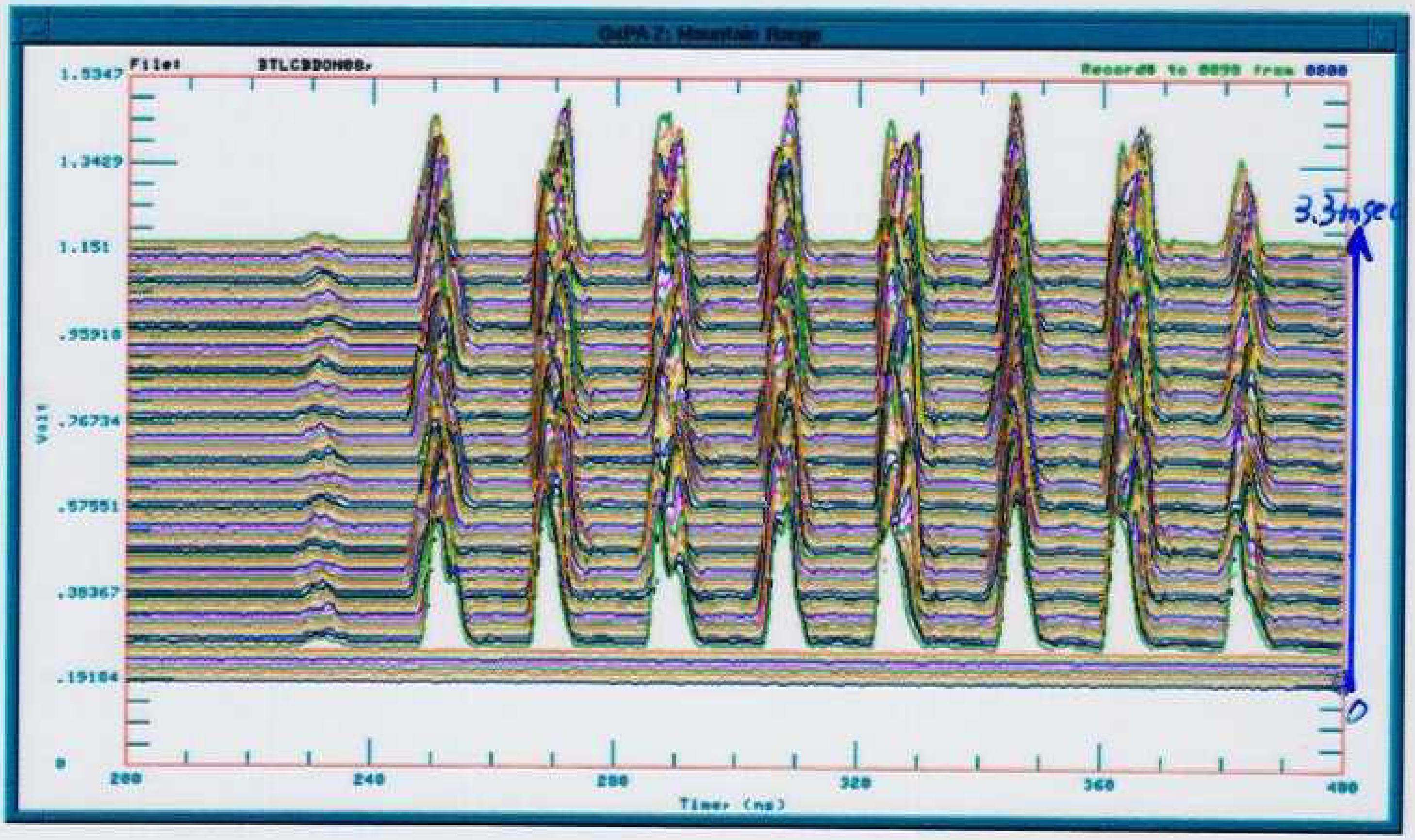


Fig. 1 - Bunch distortion during drifting ($\alpha = 4$) (concentric lines correspond to various bunch sizes)

* CERN, F-01631 CERN CEDEX, France
** Visitor to CERN from KEK, Japan

@ MI Injection (w/o damper)





@MI Injection (with damper)